S282 Astronomy

The expanding Universe

Study time: 15 minutes

Summary

This activity relates to a video sequence which examines a key concept in general relativistic cosmology – the notion of expanding space.

You should have read to the end of Section 5.4.1 of *An Introduction to Galaxies and Cosmology* before watching this video sequence.

Learning outcomes

- Appreciate the distinction between the expansion of space and movement through space.
- Understand the origin of the cosmological redshift in terms of the expansion of space.

The activity

This video sequence describes the distinction between expanding space and motion through space and explains the origin of cosmological redshift.

There are two points that you need to be aware of prior to watching the video clip. The first is that during the video sequence, Russell Stannard uses the term *horizon*. He refers to 'a galaxy that is so far away that it is beyond the horizon of the observable Universe'. You will meet the term horizon in its cosmological sense in Chapter 6, but a brief explanation is that at any given time in cosmic history, the *horizon distance* is the maximum distance that could be travelled by a physical signal. No physical signal can travel faster than the speed of light, so the horizon distance at any time since the start of cosmological expansion ($t = 0$) corresponds to the distance that light can travel in that time. Clearly, we cannot have received any physical signal from a part of the Universe that lies beyond the current horizon distance.

A second point to note is historical. This video sequence was made in 1994, when the uncertainties on the determination of the Hubble constant were substantially larger than they are at present. So Russell's final comment about not knowing the value of the Hubble constant has been superseded by advances such as a Hubble Space Telescope Key Project which you will meet in Chapter 7.

To view the sequence:

- Start the S282 Multimedia guide and then click on The expanding Universe under the 'Cosmology' folder in the left-hand panel.
- Press the Start button to run the video sequence.

After you have watched the video sequence, read the summary provided in the 'Notes' below and then attempt the following questions.

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Question 1

In what ways was the stretching rubber sheet model a good analogy for the behaviour of space, and in what ways was it inappropriate?

Question 2

How does the cosmological redshift differ from the normal Doppler shift?

Notes

The list below indicates the approximate clock time at which each new topic begins.

00:00 A distinction was drawn between two types of motion – one in which the object moves *through* space, the other where the object is borne along by an *expanding space.* Galaxies take part in both kinds of motion. Only the first is subject to Einstein's special theory of relativity, and therefore cannot exceed the speed of light. With the second type of motion, speeds of distant galaxies might well exceed the speed of light.

03:50 With regard to the cosmological redshift, it was pointed out that the increase in wavelength took place during the journey from the distant galaxy to ourselves. This was due to the fact that the space between the galaxy and ourselves expands, and this stretches out the distance between successive humps (peaks) and troughs in the wavetrain. The greater the distance travelled, the greater will be the stretching and hence the greater the redshift.

Video credits

Presenter – Russell Stannard (The Open University)

Producer – Tony Jolly (BBC)

Answers and comments

Question 1

It was a good analogy in that:

(i) it allowed a demonstration of the two types of motion

(ii) the size of the bound objects (discs/galaxies) did not change as the size of the rubber 'space' between them changed.

The analogy was inappropriate in that:

(i) the rubber belt had an edge to it, whereas three-dimensional space is thought not to have a boundary

(ii) the belt had a central point, whereas all points in three-dimensional space are on the same footing – there is no preferential central point.

Question 2

The normal Doppler shift arises when the humps (peaks) and troughs of a wavetrain have an increased separation during *emission* as a result of the movement of the source relative to the observer. This extended wavelength is then the one that travels, unchanging, across space, and is the wavelength that is subsequently received.

With the cosmological redshift, on the other hand, the wavelength during emission is normal; the extension occurs progressively throughout the subsequent journey.